Sunflower Yield and Water Use as Influenced by Planting Date, Population, and Row Spacing[1]

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ABSTRACT

Sunflower (*Helianthus annuus* L.) has only recently been grown commercially as an oilseed crop in the drier regions of the Northern Great Plains. This study was conducted to acquire preliminary information on seed yield, oil concentration, and water use for oil-type sunflower as affected by planting date, plant population, and row spacing; and to obtain an indication how these results were affected by yearly variation in precipitation and air temperature. Sunflower was grown at Mandan, N. Dak. at plant population of 25,000, 50,000, 75,000, and 100,000 plants/ha in 30- and 90-cm rows on Temvik silt loam (Typic haploboroll). Soil water withdrawal by sunflower was generally confined to the upper 150-cm soil depth. Water use by sunflower was consistently greatest for earlier plantings, and was not affected by population or row spacing. Significant positive correlations were obtained between seed yield and water use after 50% flowering. Water use before flowering was much greater in a year of high precipitation during this period than in a year when pre-flowering precipitation was lower. Seed and oil yield were usually highest for lowest populations and for 30-cm row spacing. Correlation coefficients showed that 80% of the total variation in oil concentration was accounted for by variation in water use and temperature. Oil concentration was more strongly influenced by water use than by temperature. Although late planting in 1973 increased seed yield for some of the higher plant populations, flowering was delayed until early September, increasing the frost hazard. Days from planting to flowering (50%) decreased as planting date was delayed.

***Additional index words:* Helianthus annuus L., Evapotranspiration, Water extraction by sunflower, Dryland sunflower production.**

FARMERS in the northern Plains have presently increased sunflower (*Helianthus annuus* L.) acreage, particularly oilseed varieties. Presently, production of oilseed sunflower is concentrated in the subhumid region of the northern plains, but interest in production has increased in the drier regions. However, even in the subhumid regions available information is limited upon which recommendations for cultural practices can be based. Fick (1) reported wide variation in yield among oilseed cultivars in a preliminary study in eastern North Dakota. Reasons for variation in oil concentration are not known.

Results from recent studies in eastern North Dakota (8) showed N fertilizer at 56 and 112 kg/ha, respectively increased seed yields by 650 and 850 kg/ha, and populations of 48,000 and 72,000 plants/ha increased seed yield by 370 and 930 kg/ha, respectively over that of 36,000 plants/ha. In this study, neither applied N nor increased population significantly affected oil concentration. At Swift Current, Saskatchewan, seed yields were highest at 25,000 plants/ha, with little effect from row spacings greater than 36 cm (7). Other workers (5) reported that decreasing row spacing from 91 to 46 cm increased seed yield, but that reducing spacing between plants in 46-cm rows from 46 to 15 cm reduced sunflower yield. Johnson and Jellum (3) found that yields and oil concentration of sunflower were increased in southeastern United States where sunflower was planted between mid-March and late April as compared to later plantings. In Minnesota, Robinson (6) found that seed yield was decreased when planted after late May. In south central Manitoba, Putt and Unrau (4) reported no significant differences in oil concentration of seed from different dates of harvest ranging from 1 September to 20 October.

Most of the research cited above was conducted in regions with more favorable moisture conditions than those normally encountered in the semiarid Northern Great Plains. The study reported here was designed to measure effects of planting date, plant population, and row spacing on sunflower yield, oil concentration, and water use under conditions of limited water supply.

MATERIALS AND METHODS

Field experiments were conducted at Mandan, N.Dak. in 1973, 1974, and 1975 to measure effects of planting date, plant population and row spacing on: (i) seed yield; (ii) oil concentration of seed (percent of oil in seed on a dry weight basis); and (iii) water use. Experiments were conducted on Temvik silt loam Typic haploboroll), a chestnut soil developed from shallow loess overlying glacial till. The surface 120 cm of soil contains about 32 cm of water at 1/3 bar and 16 cm of water at 15 bars tension. Data from 1975 are not presented because a severe infestation of sunflower moths drastically reduced seed set and production.

Experimental treatments included three planting dates; mid-May (early), early June (midseason), and late June (late); four plant populations (25,000, 50,000, 75,000, and 100,000 plants/ha); and two row spacings (30 and 90 cm). Main plots, consisting of planting dates, were split into subplots (6.1 × 4.3 m) by row spacing and population variables. All plots received 50 kg N/ha broadcast annually as ammonium nitrate and 22 kg P/ha as concentrated superphosphate before seedbed preparation. Previous crops on the 1973 and 1974 experimental areas were corn (*Zea mays* L.) and spring wheat (*Triticum aestivum*), respectively. All main plots were plowed in mid-May to accomodate planting procedure. Pre-emergence herbicide (Trifluralin) was broadcast and incorporated for the early planting date to control broadleaf weeds and grasses. Weed control for later plantings consisted of cultivation before seeding, and hand cultivation after plant emergence. All plots were maintained weed free.

'Peredovik' sunflower seed was drilled about 30 to 50% above the desired plant population in 30-cm rows at each planting date; 21 May and 5 and 26 June 1973, and 23 May, 10 and 27 June 1974. To establish the 90-cm row spacing, two of each three 30-cm rows were eliminated. When seedlings were about 5 cm high, plants were thinned to desired population by spacing

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Table 1. Effect of plant spacing at planting on number of plants per ha at harvest.

Planting date and year	30 cm Planting†	30 cm Harvest‡	90 cm Planting†	90 cm Harvest‡
	thousands/ha			
1973				
21 May	25.0	32.1	25.0	25.2
	50.0	51.6	50.0	48.9
	75.0	80.7	75.0	62.5
	100.0	99.3	100.0	66.2
5 June	25.0	32.3	25.0	26.9
	50.0	53.8	50.0	44.7
	75.0	71.6	75.0	65.2
	100.0	95.1	100.0	76.8
26 June	25.0	32.3	25.0	30.6
	50.0	51.6	50.0	41.5
	75.0	78.5	75.0	53.8
	100.0	91.6	100.0	61.5
1974				
23 May	25.0	34.3	25.0	25.2
	50.0	56.0	50.0	48.4
	75.0	82.7	75.0	71.6
	100.0	102.5	100.0	87.9
10 June	25.0	32.3	25.0	26.9
	50.0	53.8	50.0	49.9
	75.0	78.3	75.0	75.6
	100.0	103.9	100.0	87.9
27 June	25.0	32.3	25.0	26.9
	50.0	53.8	50.0	55.8
	75.0	73.3	75.0	69.4
	100.0	105.9	100.0	90.0

† Seedlings were thinned to provide the plant population and row spacing indicated. ‡ Population calculated according to number of heads harvested per treatment (three replications averaged).

Table 2. Sunflower seed production as influenced by planting date, plant population, and row spacing, during 1973 and 1974.

Row spacing	1,000 plants/ha	1973 Planting date	1973 Days to flowering†	1973 Seed yield	1974 Planting date	1974 Days to flowering†	1974 Seed yield
cm			no.	kg/ha		no.	kg/ha
30	25	21 May	70	1,220	23 May	68	1,880
	50		70	1,060		68	1,660
	75		71	700		69	830
	100		71	470		79	1,150
90	25		70	1,180		68	920
	50		70	940		68	1,030
	75		74	770		69	770
	100		74	670		69	820
30	25	5 June	69	1,340	10 June	63	1,880
	50		69	1,150		63	1,660
	75		69	830		64	1,470
	100		70	720		64	1,130
90	25		69	1,260		63	1,530
	50		69	960		63	1,370
	75		70	780		64	1,110
	100		70	760		64	1,110
30	25	26 June	65	1,160	27 June	63	870
	50		65	1,180		63	950
	75		68	1,440		64	740
	100		68	1,120		64	720
90	25		65	940		63	630
	50		68	850		63	630
	75		68	780		66	560
	100		68	1,010		66	540
L.S.D. 0.05							
Planting date			2	ns		1	130
Population			1	130		1	140
Row spacing			ns	90		ns	100

† Number of days from planting until 50% of plants are blooming.

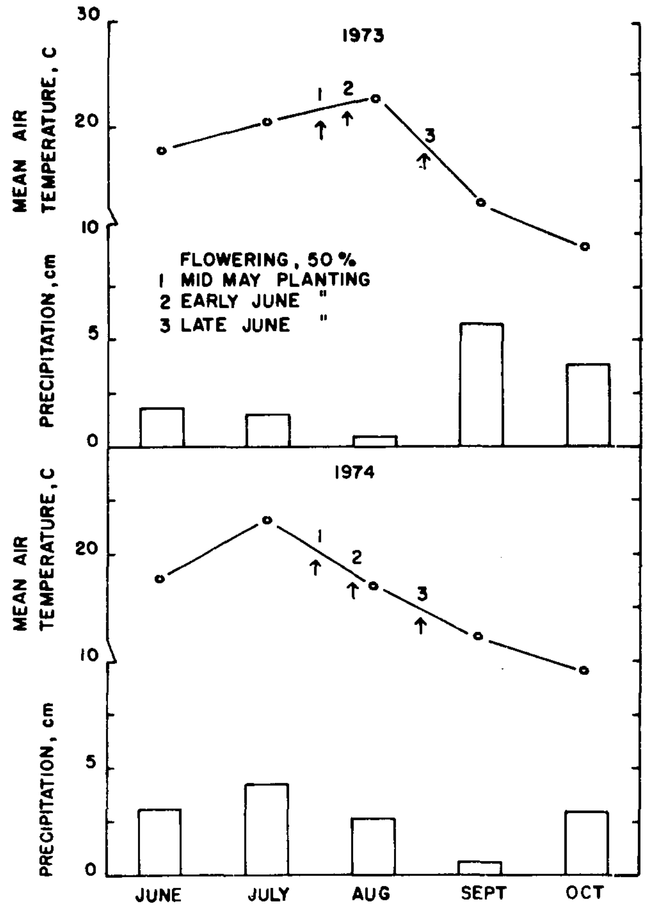

Fig. 1. Total monthly precipitation and mean air temperature (C) in 1973 and 1974 at Mandan, N. Dak. Flowering (50%) for (1) mid-May, (2) early June, and (3) late June planting was 30 July, 14 Aug., and 1 Sept. 1973; and 30 July, 12 and 30 Aug. 1974, respectively.

plants 133, 66, 44, and 33 cm apart in the 30-cm row, and 44, 22, 15, and 11 cm apart in the 90-cm row. Each year, soil water content was measured periodically on all 72 plots with a neutron moisture meter. Each access tube was placed midway between two rows, and soil water content was measured at the midpoint of each 30-cm depth interval to the 150-cm soil depth at seeding, and approximately every 30 days thereafter. In this study, water use refers to water consumed by the plant and that lost by evaporation between seeding and harvest. No runoff was observed from the experimental site. Water use was calculated by subtracting initial soil water content from water content of later sampling date and adding precipitation within that period. In both years, soil water contents were measured within 6 days or less of date of 50% flowering.

Harvest dates for early, midseason, and late plantings were 13 and 25 Sept., and 23 Oct. 1973; and 22 and 30 Sept., and 3 Oct. 1974, respectively. First frost was on 15 Sept. 1973, and 2 Sept. 1974. Sunflower heads were bagged at early seed development to prevent bird depredation. Seed yields were determined by hand harvesting heads from 5.6 m^2/plots, and oven drying at 70 C. Oil concentration was determined on a 38-cm^3 sample by a nuclear magnetic resonance procedure (2). To determine oil yield, seed yield was multiplied by oil percent divided by 100.

Precipitation was measured at the plot site each year. Air temperature was recorded at the Research Center, 5 km from the plot site. A threshold temperature of 10 C was substracted from daily maximum air temperatures to calculate degree days for the period between 50% flowering to harvest. During this period in the Northern Great Plains, daily minimum tempera-

Table 3. Effect of planting late, population, and row spacing on oil concentration and oil yield.

Row spacing	1,000 plants/ha	1973 Planting date	1973 Oil conc.	1973 Oil yield	1974 Planting date	1974 Oil conc.	1974 Oil yield
cm			%	kg/ha		%	kg/ha
30	25	21 May	38.8	470	23 May	46.7	880
	50		38.0	400		47.0	780
	75		37.5	260		42.9	360
	100		35.7	170		44.5	520
90	25		40.9	500		46.3	430
	50		39.3	370		44.5	460
	75		39.3	300		43.8	340
	100		39.1	260		43.9	410
30	25	5 June	41.5	550	10 June	43.9	830
	50		40.9	470		44.0	730
	75		39.7	330		44.0	650
	100		40.7	290		41.0	430
90	25		42.8	540		44.2	680
	50		43.0	410		42.8	580
	75		41.1	320		41.9	460
	100		40.3	310		41.3	460
30	25	26 June	43.4	500	27 June	28.3	250
	50		43.7	520		32.4	250
	75		44.2	640		30.9	230
	100		45.5	510		32.8	240
90	25		43.1	410		30.3	190
	50		44.2	380		29.7	190
	75		44.5	350		29.0	160
	100		43.8	440		28.9	150
L.S.D. 0.05							
Planting date			0.6	70		1.5	70
Population			ns	50		ns	60
Row spacing			0.6	40		ns	40

tures are normally below the assumed 10 C threshold temperature, and daily range between maximum and minimum is large, frequently approaching 30 C. The low minimum and wide range in daily temperature variation gives relative low daily mean temperatures that do not truely reflect growing conditions during daylight hours. Consequently, these conditions may better be expressed in terms of daily maximum rather than daily mean temperatures. Oil concentration, water use, and seed yield were therefore related by multiple regression analysis to degree days calculated by subtracting 10 C from daily maximum. Selected values of 400, 800, and 1,200 degree days were fitted to the regression formulas to illustrate the relationships derived.

RESULTS AND DISCUSSION

Climate and Seed Yield

Precipitation in the period before flowering (50% plants in bloom) was 2.1 cm higher in 1974 than in 1973 (Fig. 1). However, during the period after flowering, precipitation was higher in 1973 than in 1974, favoring late planting more in 1973 than in 1974. Temperatures increased from June to August in 1973, whereas in 1974 August was cooler than July. Temperatures after flowering of late plantings were similar in both years. Thus the 2 years of study represent a wide contrast in precipitation and temperature patterns. 1973 was hot and dry before flowering, followed by good growing conditions, and 1974 was near ideal early season growing conditions, followed by drought after flowering.

Plant stand at harvest was influenced by year and by plant competition (Table 1). Final plant stands were lower in 90-cm row spacings than in 30-cm row spacings, and were also lower in 1974 (relatively low precipitation after flowering) than in 1973 (relatively

Table 4. Soil water content (0- to 120-cm depth) at planting, flowering (50%), and harvest as affected by date of planting and plant population.

Planting date and population	Sampling date† Planting	Flowering‡	Harvest
1,000 plants/ha		cm	
		1973	
21 May			
25	22.6	15.6	13.5
50	22.9	15.2	13.7
75	23.0	14.4	13.1
100	22.8	15.2	13.8
5 June			
25	23.3	14.2	16.0
50	25.0	13.7	16.0
75	24.4	12.8	14.8
100	23.9	12.9	15.8
26 June			
25	24.0	16.5	17.6
50	23.9	16.1	17.4
75	23.8	15.9	17.8
100	23.8	15.2	16.8
L.S.D. 0.05			
Planting date	ns	1.8	1.1
Population	ns	ns	1.0
Population X date	ns	1.6	ns
		1974	
23 May			
25	34.4	20.1	18.7
50	33.8	19.1	17.9
75	33.6	17.6	17.6
100	32.4	16.3	16.4
10 June			
25	32.5	21.2	17.1
50	31.6	19.1	16.5
75	33.1	21.0	18.2
100	34.8	22.0	18.8
26 June			
25	33.6	20.6	17.0
50	35.0	21.8	18.4
75	34.4	20.3	17.6
100	33.8	21.2	18.7
L.S.D. 0.05			
Planting date	ns	ns	ns
Population	ns	ns	ns
Population X date	ns	ns	ns

† Sampling dates at planting, flowering and harvest since 21 May, 11 and 28 June 1973, 29 May, 12 and 28 June 1974; 30 July, 28 and 28 Aug. 1973, 6 and 6 Aug., and 26 Aug. 1974; and 14 and 26 Sept., and 24 Oct. 1973, 23 Sept., 3 and 9 Oct., 1974. ‡ Soil water readings were within 6 days of 50% flowering.

high precipitation after flowering. Some of the plants at the two highest population, particularly in 90-cm row, were thin and underdeveloped with little or no heads formed. At the lower populations, harvest population was sometimes greater than population after thinning because less competition allowed some plants that were thinned out to be reestablished.

Number of days from planting to flowering decreased in both years as planting was delayed (Table 2). High population also delayed flowering by 1 to 4 days. Seed yields were highest for low populations and for 30-cm row spacing in both years.

Oil Concentration and Oil Yield

Each year, planting date had a variable effect on oil concentration (Table 3), with late planting having highest concentration in 1973, but lowest in 1974. These results suggest that the dry conditions present during seed development in late 1974 reduced oil concentration. Other workers (3, 6) reported decreased oil concentration from late planting. Although low

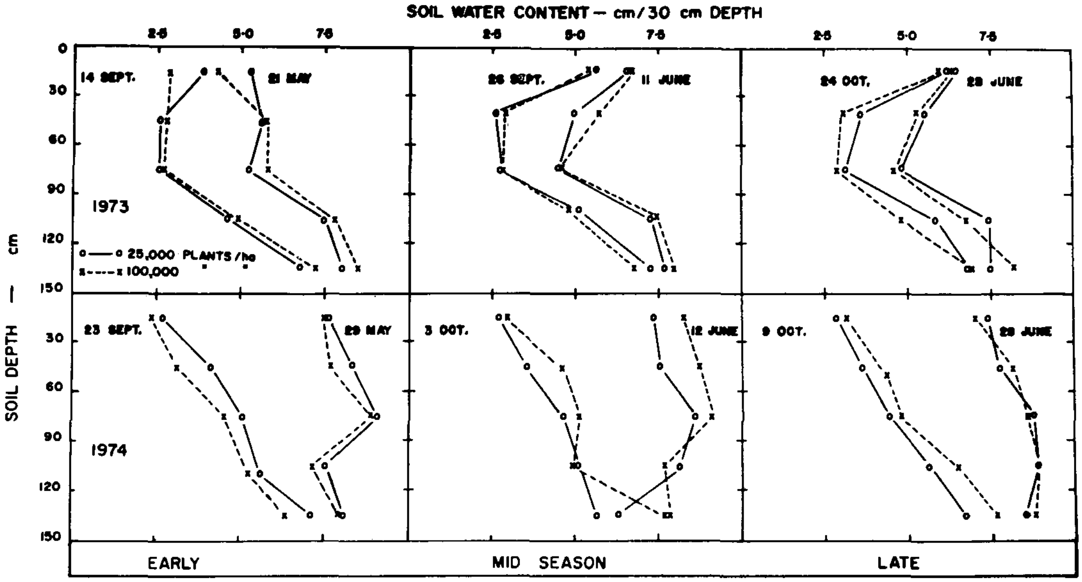

Fig. 2. Soil water content at seeding and harvest for 25,000 and 100,000 plants/ha in 1973 and 1974.

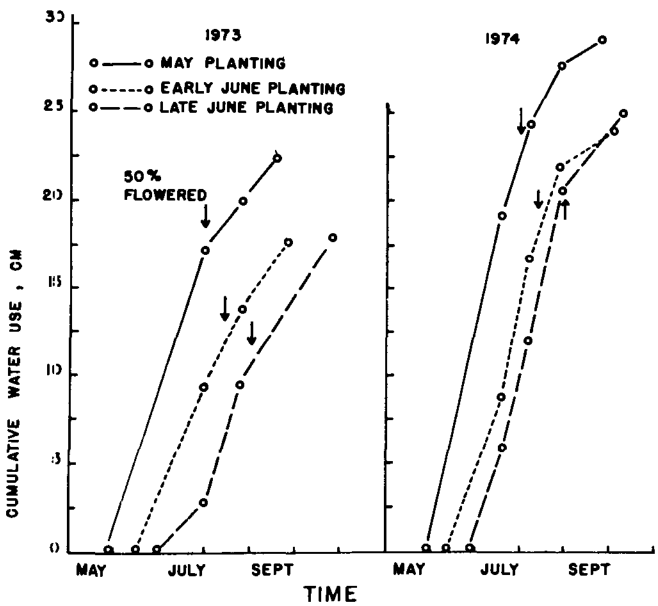

Fig. 3. Cumulative water use of sunflower as influenced by planting date.

population produced larger sunflower heads, this did not affect oil concentration in either year. However, larger heads do seem to increase oil yield per unit area. Plant population also failed to affect oil concentration. These results agreed with those from other North Dakota studies (8).

Oil yield (Table 3) was generally highest for the low plant population, primarily because seed yield was greatest for this population. For mid-May, early and late June plantings, average oil yield was 340, 400, and 470 kg/ha, respectively in 1973, and 520, 600, and 210 kg/ha, respectively in 1974. Oil yield for 30-cm row spacing was 24% greater than that from 90-cm rows. These results suggest that, regardless of precipitation patterns, all yields would be near maximum for sunflowers seeded by early June at 25,000 plants/ha in 30-cm rows.

Soil Water Content

Data are given in Table 4 on soil water content (0 to 120-cm depth) at planting, flowering, and harvest of each year. Soil water data at flowering were collected within no more than 6 days from date of 50% flowering. In general soil water content declined as the growing season progressed. Row spacing had no significant effect on soil water content.

Only in 1973 was soil water content significantly affected by planting date and date × plant population interaction at flowering. By harvest, plant population and planting date significantly affected soil water content. In both 1973 and 1974 soil water depletion was greater during the early part of the season than after flowering, leaving relatively little available soil water for plant use during seed development. Therefore, water use after flowering was highly dependent on precipitation received at that time.

Average soil water contents by 30-cm depth intervals to 150-cm depth at planting and harvest are presented in Fig. 2. Differences in water extraction patterns were affected primarily by planting date. Population had relatively little affect on extraction patterns.

Soil water content at the 120- to 150-cm depth at harvest was signficantly different from that at seeding for most planting dates and populations. However, regardless of plant population, projections from the information in Fig. 2 indicate that sunflowers were not able to extract appreciable available water from soil depths below 150 cm.

Cumulative water use as a function of planting date is given in Fig. 3. More water was available and was used during the vegetative growth period than during the seed development period. An exception occurred

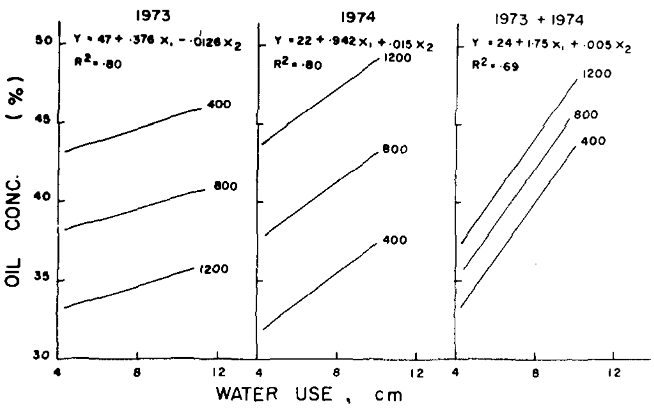

Fig. 4. Regression of oil concentration on water use after 50% flowering stage for 400, 800, and 1,200 degree days (y = oil concentration, x_1 = water use, x_2 = degree days).

when precipitation in late summer was high (1973) and water use after 50% flowering by late plantings equalled water use before flowering. Water use before flowering was much greater in 1974, a year when early season precipitation was relatively high. In both years, mid-May plantings resulted in higher cumulative water use than did later plantings. Plantings made after mid-May were similar in total cumulative water use. Plant population and row spacing had little effect on average total water use. Average (2-year) total seasonal water use was 22.9 and 22.6 cm for 30 and 90-cm row spacing, and 22.6, 22.9, 23.0, and 22.6 cm for 25,000, 50,000, 75,000, and 100,000 plants/ha, respectively. These data indicate that total seasonal water use by various plant population do not greatly differ by harvest.

Linear regression analysis showed that water use for the period after 50% flowering correlated significantly ($r = 0.43^*$ and 0.51^*) with seed yield in 1973 and 1974, but correlation coefficients were too low for predictive purposes. In neither year was total water use from seeding to harvest significantly correlated with seed yield. Seed yield was correlated significantly ($r = 0.40^*$) with degree days only in 1974.

Figure 4 shows the results of multiple regression analysis of oil concentration with water use and degree days for the period from 50% flowering to harvest. Results are expressed in terms of the relationship between water use and oil percentage at 400, 800, and 1,200 degree days (representative of the experimental range covered). Correlation coefficients showed that 80% of the total variation in oil concentration was accounted for by variation in water use and temperature Degree days were negatively related to oil concentration in 1973, but were positively related in 1974. Oil concentration correlated positively with water use in both years, indicating that water use was more closely related to oil concentration than was degree days.

Although these correlation data showed that oil concentration was affected by both water and temperature relations, they are inadequate to provide quantitative information of predictive value.

CONCLUSION

For high seed yield and oil concentration, dryland sunflower should be planted before mid-June. Even though the 27 June planting did provide good seed yields in 1973, favorable late-season precipitation resulted in flowering continuing until early September, increasing the possibility of frost damage. Seed and oil production were highest from the low population (25,000 plants/ha), and from 30-cm row plantings.

High water use after the 50% flowering may be more beneficial to seed production than in total seasonal water use (seeding to harvest). Regression analyses indicated a relationship existed between available water supply after flowering and oil concentration of seed, but other parameters are needed to explain the relationship. In general, neither plant population nor row spacing influenced total water use and water was extracted to about the 150-cm depth. A row spacing of 30-cm favored dryland seed yield under weed-free conditions.

Since the 2-year study varied widely in growing conditions, especially before flowering in comparison to after flowering, these results embrace growth responses over a wide range of variation in temperature and precipitation. Therefore, it is felt that these results, while not precise enough to use for predictive purposes, do provide a first approximation of the cultural requirements for sunflower production in a temperate semiarid climate. Such information has been previously lacking.

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